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ROLE OF GREENHOUSE GAS INVENTORIES IN CLIMATE CHANGE MITIGATION AT INSTITUTIONS OF HIGHER EDUCATION

A Thesis

Submitted to the Bayer School of Natural and Environmental Sciences

Duquesne University

In partial fulfillment of the requirements for

the degree of Master of Science

By

Sadaf Tehmina

May 2015

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2015

ROLE OF GREENHOUSE GAS INVENTORIES IN CLIMATE CHANGE MITIGATION AT INSTITUTIONS OF HIGHER EDUCATION

By

Sadaf Tehmina

Approved April 7, 2015

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ABSTRACT

ROLE OF GREENHOUSE GAS INVENTORIES IN CLIMATE CHANGE MITIGATION AT INSTITUTIONS OF HIGHER EDUCATION

By

Sadaf Tehmina

May 2015

Dissertation supervised by Dr. John Stolz.

Despite hundreds of Institutions of Higher Education (IHE) pledging action against climate change, there is little research on how to effectively enable these initiatives. This study utilizes a survey to analyze the role of greenhouse gas inventories (GHGI) in climate change mitigation within IHE. Among 62 responses, 46 indicated GHGI was helpful in decisions regarding emission reduction measures; 54 reported having a climate action plan (CAP) or sustainability policy (SP); 49 used GHGI in forming the CAP/SP. 95% of the respondents signed the ACUPCC pledge. When GHGI was used the IHE was more likely to have higher emission reductions (above 10%) than when the GHGI was not (10% and below). GHGI helped institutions in: identifying sources and quantifying emissions; saving costs; monitoring emissions reduction; raising

awareness about climate change; and teaching. This study suggests how IHE stakeholders can better enable GHGIs and implement impactful climate change initiatives.

DEDICATION

To Ammi and Daji for their endless support.

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LIST OF ABBREVIATIONS

ACUPCC	American College and University Presidents' Climate Commitment
AASHE	Association for the Advancement of Sustainability in Higher Education
CO_2	Carbon dioxide
CA-CP	Clean Air-Cool Planet
CAP	Climate action plan
GHG	Greenhouse gas
GHGI	Greenhouse gas inventories
GHG Protocol	Greenhouse Gas Protocol
IPCC	Intergovernmental Panel on Climate Change
IRB	Institutional Review Board
IHE	Institutions of higher education
LEED	Leadership in Energy and Environmental Design
CH_4	Methane
N_2O	Nitrous oxide
SPSS	Statistical Package for the Social Sciences
SP	Sustainability policy
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute
U.S. EPA	United States Environmental Protection Agency

Chapter 1: Background

Hundreds of institutions of higher education (IHE) are leading the way of combating climate change. They are playing their role by both reducing their greenhouse emissions and instilling in their students a sense of responsibility towards this challenge. A common pattern is observed among the institutions that are trying to reduce their carbon foot print – one of the first steps in the process is conducting a greenhouse gas inventory (GHGI) of the institution. While IHE scramble to understand and embrace climate change issues, there is a dearth of information and research regarding how and why these institutions should go about these initiatives. This research focuses on the GHGI of the institutions. The aim is to study and understand the role the GHGI play in climate change mitigation within IHE, along with the way the GHGIs are being used and the purposes they serve. In addition, the institutional factors that can affect the process are analyzed with results summarized so that administrators, faculty, and students can take the insights provided from this study to better enable future GHGI and climate change initiatives.

1.1. Greenhouse gases and climate change

Climate change refers to a natural or human induced change in the average temperature of the earth that prevails for years (Pachauri & Reisinger, 2008). The drivers of climate change include increasing greenhouse gases (GHGs) and aerosols in the atmosphere, changes in land surface, and variations in solar radiations (Pachauri & Reisinger, 2008). Among these drivers the GHGs – the atmospheric gases that absorb and release infrared red rays – play a significant role in climate change. These gases are produced both naturally and by anthropogenic activities. Anthropogenic activities produce four main GHGs: carbon dioxide, methane, nitrous oxide, and halocarbons. The amount of these gases build up in the atmosphere if the amounts released are greater than those removed. The concentrations of carbon dioxide, methane, and nitrous oxide in the global atmosphere have escalated prominently due to anthropogenic activities since 1750 (Pachauri & Reisinger, 2008). Furthermore, GHG emissions have grown by 70% from 1970 through 2004 (Pachauri & Reisinger, 2008). The IPCC Fourth Assessment Report released in 2007 predicted that the GHG emissions around the world will keep increasing over the upcoming years (Pachauri & Reisinger, 2008). Discussing future climate change, the report projected a temperature increase of 0.2 degree Celsius per decade over the next couple of decades (Pachauri & Reisinger, 2008).

1.2. Climate change and the institutions of higher education

Climate change is a growing concern for stakeholders within and outside of Institutions of Higher Education (IHE). Efforts at the international, national, and local levels are being made to mitigate the anthropogenic climate change. The term mitigate here refers to lowering GHG emissions into the atmosphere to check climate change (Pachauri & Reisinger, 2008). We all contribute to climate change in our daily lives by either involving in activities that directly release GHGs, for instance driving, cooking, and so on, or by purchasing and using products whose production processes generate GHGs. It is therefore important to realize that we all have a responsibility of acting towards climate change mitigation. Governments, businesses, institutions, and individuals all have a part to play in fighting this serious threat. This study has focused on the role of institutions of higher education in particular because of their unique position in the fight against climate change – IHE can contribute to dealing with this challenge by both reducing their emissions and educating about climate change (Zhaurova, 2008; Hale, 2007; Rappaport & Creighton, 2007; Knuth et al., 2007).

As of 2011, there are more than seven thousand institutions of higher education in the United States (Synder & Dillow, 2013). These institutions comprise thousands of campuses and buildings, and accommodate millions of students, all of whom together leave a considerable carbon footprint (Zhaurova, 2008; Association of Climate Change Officers, 2011). According to Rappaport's study (2008), since 1990s the GHG emissions of IHE have increased because of campus expansion and greater electricity consumption (as cited in Zhaurova, 2008). Knuth et al (2007) stated that some large universities can release GHGs up to the level of small cities (as cited in Zhaurova, 2008). In 2005 the IHE generated about 2% of the total emissions of the U.S. in that year (Association of Climate Change Officers, 2011; Sinha et al., 2010). This amount is comparable to roughly one-fourth of the GHG emissions of California (Sinha et al., 2010). According to one study, the U.S. EPA (2009) estimated that in 2007 the colleges and universities were responsible for emitting 1.6% of the total emissions of the country that year (as cited in Klein-Banai & Theis, 2011). Thus, GHG emissions of the IHE constitute a significant target and by reducing these emissions institutions can play an important role.

Besides reducing their carbon footprint, IHE have another very important role which is unique to them – inculcating an attitude of responsibility towards the challenge of climate change mitigation in millions of students that are the leaders of tomorrow (Zhaurova, 2008; Knuth et al., 2007; Rappaport & Creighton, 2007; Hale, 2007). David Orr, Special Assistant to the President of Oberlin College on Sustainability and the Environment, and author of several books said universities are quite capable of driving the transition towards sustainability (as cited in Hale, 2007). Higher education can take up a leadership role and impact the climate change through education and scientific research (Velazquez et al., 2006; Jaye, 2011; Zhaurova, 2008; & Rappaport & Creighton, 2007). As mentioned in one study, Knuth et al expressed, owing to their educational duty institutions of higher education are morally responsible to confront climate change challenge (Zhaurova, 2008). Students can be taught to achieve carbon neutrality by incorporating sustainability into their curriculum (Daley, 2012). Educational institutions can play a guiding role – the success stories of achieving carbon neutrality at these institutions can also assist in guiding other academic and non-academic institutions (Zhaurova, 2008).

On account of their unique role, the IHE were studied for climate change mitigation strategies and action. Looking at the websites of universities and colleges, several actions taken up for tackling climate change were pointed out: GHG emission reduction through energy conserving behavior and energy efficiency retrofitting; shifting to renewable energy sources; organizational changes to address climate change related activities; policy intervention to accommodate mitigation; and so on. These actions varied from institution to institution depending upon internal and external factors. It was observed that many institutions had also committed to voluntary programs for addressing climate change. The most prominent among them was The American College and University Presidents' Climate Commitment (ACUPCC). The commitment requires the signatories to: submit a completed greenhouse gas inventory (GHGI); set a timeline for becoming climate neutral; take emission reduction steps promptly; incorporate sustainability into the curriculum; and make the GHGI, climate action plan (CAP), and progress report available to public (American College and University Presidents' Climate Commitment, n. d.; Zhaurova, 2008).

An important observation was made while studying the way the institutions were addressing climate change – most of them had conducted GHGI of their institution's emissions. This observation coupled with the fact that ACUPCC requires its signatories to conduct a GHGI pointed out a question: What is a GHGI and what is its significance? Further literature review was conducted to seek answer to the question, and is discussed in subsequent sections.

1.3. What is a greenhouse gas inventory?

Different entities adopt different strategies to reduce their emissions, depending upon their emission sources, types, amounts, and so forth. According to the United States Environmental Protection Agency (U.S. EPA), entities that plan to decrease their carbon-footprint typically initiate by conducting a Greenhouse Gas Inventory of their facility or entity (United States Environmental Protection Agency, n. d.). A GHG inventory is an instrument for quantifying the greenhouse gas emissions of any facility such as a company, an industry, an institution, a city, and so forth. The U.S. EPA defines a greenhouse gas inventory as a tool that computes the amount of GHGs released into or eliminated from the atmosphere during a certain time. An inventory establishes the baseline information that can be used for different purposes such as, assessing and recording emissions, framing mitigation plans, and monitoring progress (United States Environmental Protection Agency, n. d.).

Many local governments, companies, industries, institutions, and schools in the United States and in other countries, have conducted the GHGI. To illustrate, in United

States among the cities that have conducted the GHGI are Berkley, Denver, Atlanta, Chicago, New Orleans, Bloomington, New York, Portland, and Pittsburgh (United States Environmental Protection Agency, n. d.). In 2006, the city of Pittsburgh, Pennsylvania had published its GHGI for the year 2003 and had also adopted a CAP in 2008 (Parson, 2010). Similarly, numerous educational institutions across the country have also conducted inventories. To name a few, from among those whose reports were found on the internet; Western Michigan State University, Harvard University, University of Pittsburgh, Clemson University, Eckerd college, Colby college, and many more.

1.4. Conducting an inventory

A GHG inventory is typically conducted through following steps (Andrews, 2008; Dautremont-Smith, 2009).

i. Defining boundaries

Boundaries have to be defined early in the process of conducting an inventory. There are three types of boundaries (Ranganathan et al., 2004; Dautremont-Smith, 2009).

a. Organizational boundary

Organizational boundaries refer to determining which portions of an institution, as in departments, campuses, schools, etc. that are either held or directed by the institution, will be included in the inventory (Ranganathan et al., 2004).

b. Operational boundary

Operational boundaries refer to determining which emissions are caused by an institution's operational activities. These include both direct and indirect emissions, and are categorized in three scopes (Ranganathan et al., 2004; Dautremont-Smith, 2009).

Scope 1 emissions

These include the direct emissions that are produced by sources held and directed by the institution. For instance, emissions from vehicles owned by an institution, emissions from laboratory procedures, and so forth are included (Ranganathan et al., 2004; Dautremont-Smith, 2009).

Scope 2 emissions

These include indirect emissions from purchased energy including electricity, steam, and cooling (Ranganathan et al., 2004; Dautremont-Smith, 2009).

Scope 3 emissions

These include the other indirect emissions from sources that are not held or operated by the institution. For instance, emissions from managing solid waste of the institution, commuting, purchased products, and so on (Ranganathan et al., 2004; Dautremont-Smith, 2009).

c. Temporal boundary

Temporal boundary refers to determining the time period for which emissions are measured and reported. For instance, emissions are reported on an annual basis (Dautremont-Smith, 2009).

ii. Selecting a tool

The next step is selection of a tool for calculating emissions. Most of the institutions of higher education use the Campus Carbon Calculator developed by the organization Clean Air-Cool Planet (American College and University Presidents' Climate Commitment, n. d.; Zhaurova, 2008). The Campus Carbon Calculator was initially based on an Excel spreadsheet, but recently has been converted to a web-based tool. Some institutions, for example Yale University, have developed their own customized tools for emission estimations.

Tools for emissions calculations are mostly based on the standards developed by the Greenhouse Gas Protocol (GHG Protocol). The GHG Protocol is a combined program developed by the World Business Council for Sustainable Development (WBCSD) and the World Resource Institute (WRI) to provide GHG standards and tools for use by companies, businesses, and organizations to assess and manage their GHG emissions (Greenhouse Gas Protocol, n. d.).

iii. Gathering data

The next step is to figure out what type of data is required and where to acquire it from. The required data mostly comprise energy consumption, commuting, air-travel, and so on. This information is gathered from various parts of an institution such as administration, facilities, faculty, students, etc. and some external sources such as utility companies. Gathering data is typically the most time consuming and challenging part of conducting an inventory (Andrews, 2008).

iv. Quantifying and reporting emissions

The gathered data is entered into the emissions calculation tool and the program is run to generate results. The results are then analyzed and a GHG inventory report is prepared (Andrews, 2008). Emissions of all the accounted greenhouse gases are reported in terms of CO_2 equivalents (Bader & Bleischwitz, 2009). The metric unit is used for reporting emissions quantity (Association for the Advancement of Sustainability in Higher Education, n. d.).

Chapter 2: Research aim and hypotheses

As stated before, one of the first steps the ACUPCC requires its signatories to take is to perform a GHGI. The ACUPCC has 695 signatories as of January 2015. Among them about 570 have submitted at least one or more GHGI reports; the total number of reports submitted so far is 2151. About 533 institutions have formulated climate action plans (CAPs) and around 364 have submitted their progress reports (American College and University Presidents' Climate Commitment, n. d.). A question was asked in this research – what role do GHGI play in assisting the institutions in reducing their emissions?

ACUPCC represents around 700 of more than 7000 IHE in the country, which is around 10%. It is to be noted many institutions that have not signed the ACUPCC have also taken up climate commitments of their own. For instance Harvard University has not signed the ACUPCC, but it has set its own climate change related goals. There run some similarities between both ACUPCC signatories and non-signatories when it comes to addressing climate change – performing GHGI, and forming and implementing CAPs. At IHE, typically the first step in tackling climate change is performing a GHGI (Zhaurova, 2008). There are several reasons for conducting a GHGI; however, as pointed out in literature the main objective is to establish a baseline of GHG emissions generated by campus activities (Moerschbaecher & Day Jr. 2010).The inventory helps in determining and recording sources of emissions in a systematic manner (Zhaurova, 2008).

According to the U.S. EPA, inventories are used by policy and decision makers to record GHG emissions, to form strategies and policies for climate change mitigation, and to evaluate progress (United States Environmental Protection Agency, n. d.). AASHE states the inventory as a key step in developing a “climate action plan” (CAP) (Association for the Advancement of Sustainability in Higher Education, n. d.). A research article “Preparing US Community Greenhouse Gas Inventories for Climate Action Plans” notes that a GHG inventory can help in developing a CAP, establishing worthwhile targets, and assessing progress (Blackhurst et a., 2011).

Further literature review assisted in understanding the use of the information generated by the GHGI. Two common themes were found regarding the use of the information – for informing decisions and for forming climate action plans or climate change related policies.

2.1. Use of information in decision making

The inventory report of Louisiana State University stated one of the purposes of the information was to identify potential measures to reduce future GHG emissions. It further stated that GHGI can help in determining energy requirements and identifying conservation choices (Moerschbaecher & Day Jr. 2010). Another study maintained that the inventory initiated the identification of mitigation actions possible (Zhaurova, 2008). Yale University had conducted an inventory of emissions from purchasing “goods and services”, with an aim to generate information that will facilitate decisions to reduce these emissions (Thurston & Eckelman, 2011). In the “Guide to climate action planning”, it was stated that most of the institutions in the U.S. performed GHGI as one of the initial steps; it helped in spotting the chief emitters and thereby, selecting the major reduction options. It illustrates with the example of Pomona College which used the inventory to single out the most energy consuming buildings (Eagan et al., 2008)

Based on the discussion in this subsection, that inventories facilitate decisions regarding suitable emission reduction action an association seemed possible between the use of GHGI in decision making and the emission reduction achieved. Thus, a hypothesis was formed about the role of GHGI in climate change mitigation within institutions – the use of GHGI in informing decisions is associated with the GHG emissions reduced within institutions of higher education.

2.2. Use of information for forming climate action plans or policies

It is asserted that institutions that tend to start climate action planning must begin by quantifying a baseline of their emissions (Eagan, 2008; Jaye, 2011). In an article about the GHGI of the University of Illinois in Chicago, it was stated that the institution had conducted the GHGI as one of the initial steps towards reducing the institution's emissions. The inventory was described as an instrument for setting targets, forming strategies, and establishing policies. It further added that the GHGI laid the foundation of climate action planning and policy making (Klein-Banai et al., 2010). This last point was reaffirmed in two other reports (Hale, 2007; Eagan, 2008). A five-year report of Tuft's Climate Initiative also maintained that performing the inventory was an initial step for determining tactics, comparing different options, planning mitigation activities, and monitoring improvement (Tufts climate initiative, 2004). The "Guide to climate action planning" had discussed a few cases where GHGI were helping institutions form climate action plans. One example was Oberlin College that was reported to be working on inventory and was intending to use it for climate action planning (Eagan, 2008). It was inferred from Briselden (1998) that benchmarking the GHGI information can improve the overall planning and assist the decision makers in setting meaningful targets (as cited in

Jaye, 2011). Sometimes, policy decisions are also based on the inventory information. For instance, Emory Healthcare GHG emissions inventory report stated that policy actions were meant to arise from the results of the completed inventory report (Canon, W. (2012).

This discussion on how inventories inform climate plans and policies seems to suggest that inventories - through facilitating climate action planning - can assist institutions in achieving emission reductions. Thus, second hypothesis of this research was formed – the use of GHGI in forming either a climate action plan or policy is associated with the GHG emissions reduced within institutions of higher education.

2.3. Other uses of GHGI

The software programs that are used for calculating emissions can sometimes be used for assessing the impact of different emission reduction measures. For instance, they can help estimate the amount of carbon dioxide equivalents that can be prevented if a certain measure is taken, for example, improving building insulation versus another measure such as installing more heating systems. Such comparisons assist informed decision-making regarding more meaningful and cost-effective reduction measures (Bader & Bleischwitz, 2009). According to the “Guide to climate action planning”, the 2008 version of CA-CP calculator can help select worthwhile mitigation projects based on accounting expected costs and projected emission reductions (Eagan, 2008).

Inventories can also help institutions save costs. Through inventories, a better understanding of energy usage areas and patterns can be gained, and the highest usages can be determined. Strategies can then be developed and implemented for conservation, use-reduction, or efficient-use which can result in significant cost savings (United States

Environmental Protection Agency, n. d.). To illustrate, Clemson University determined that most of its emissions result from electricity use and it aims to pursue projects that will reduce emissions from this source (Clemson's Carbon Footprint. (n.d.).

A research paper on the “Quantitative analysis of factors affecting greenhouse gas emissions at institutions of higher education” in referring to the inventory as a “sustainability indicator” stated that GHGI can be used to monitor variations over time (Klein-Banai & Theis, 2011). The GHGI is a tool for keeping track of the emissions footprint and for measuring progress by observing the emission growth and reduction trends (Klein-Banai et al., 2010; Letete et al., 2011). Institutions that have conducted inventories of multiple years can read the differences in their annual CO_2 equivalent emissions in metric tons ($MTCO_2$/yr.) for different years and assess how their footprints vary as a result of changes in campus operations. This can assist in evaluating the success or failure of different interventions for emission reductions and assess progress towards the goal (Jaye, 2011; Klein-Banai et al., 2010). Similarly, it can also help in determining emission increases resulting from new construction, campus expansion, growing student population, or increased research activities (Association for the Advancement of Sustainability in Higher Education, n. d.). Institutions that take emission reduction measures without conducting the inventory can have difficulty in assessing progress, particularly in situations where net growth in emissions outweighs the emissions reduced (Jaye, 2011).

GHGI are also identified as means of raising awareness and motivating behavior change (Association for the Advancement of Sustainability in Higher Education, n. d.; Tufts climate initiative, 2004; Zhaurova, 2008). For instance, the inventory through pointing out emissions from daily activities such as driving or electricity usage can help create consciousness of individual carbon-footprint (Association for the Advancement of Sustainability in Higher Education, n. d.). Quantifying emissions can make them more real for people (Brase, 2009). Institutions in their efforts to reduce emissions can make use of inventory results to enlighten students about their carbon footprints and thereby, inspire behavioral changes, such as energy-conserving behavior among their students. Behavior-based reductions can come from simple actions like walk or bike instead of driving, turn computers to sleep mode when not using, recycle waste instead of throwing away, and so on (Brase, 2009). Institutions can disseminate the inventory results among students through forums such as Blackboard, pamphlets, notice boards, and so forth; and help inspire realization and action among its students. Inventories can also prove useful for education purposes. For instance, the information generated by GHGI can be utilized in teaching students of engineering and architectural programs about designing buildings that have lower carbon footprint (Jaye, 2011). Another pedagogical use of GHGI is involving students in conducting inventories to help them learn how to assess the carbon footprint of campus operations.

2.4. Aim and objectives of research

Conducting inventories takes considerable effort and time, and in some cases financial outlays too. Through literature review it was ascertained that several hundred institutions of higher education in the United States have conducted GHG inventories. Many among them have formulated CAPs and have undertaken GHG emission reduction measures. The literature maintains that GHGI are meant to facilitate the process of climate change mitigation; however, no research has been conducted to assess this aspect on ground so far. This research intends to assess so and analyze the predicted versus actual uses of inventories, all with the aim of determining the role of GHGI in climate change mitigation within IHE. The purpose is to generate information that can contribute towards making the efforts of IHE for achieving emission reductions more effective.

The overall aim of this research is expected to be achieved by fulfilling following objectives:

- To determine if the GHGI is used in facilitating climate change mitigation within the IHE.
- To assess the variables that affect the way the inventory was used.
- To assess the effectiveness of GHGI.

Chapter 3: Methods

3.1. Research approach and design

In designing this research project, Miller and Salkind (2002) recommend a multi-method based approach to data collection. The subject of this research was GHG inventories of institutions of higher education in the United States. Due to practical reasons it was not possible to study the inventory of each and every institution in the country, so a conclusion was to be reached about the subject based on an analysis of a targeted sample.

3.2. Population and sample selection

The initial goal was to have a sample that would include all the institutions of higher education in the United States that have conducted at least one GHG inventory. However, it was found that there is no single forum from where a list of all the institutions that have conducted GHGI can be obtained. The most comprehensive list was that of ACUPCC which comprised GHGI reports of 695 members, but in order to derive a more representative sample an effort was made to include institutions outside of ACUPCC as well. To do so two more forums of institutions that were committed to reducing their emissions were included – U.S. EPA's Energy star program and AASHE STARS program. Thus a list of about 890 IHE working to reduce their emissions was compiled from three publically accessible forums. The list was sorted randomly using Microsoft Office Excel so that a random sample could be drawn where every institution had equal chances of being selected. The target sample size was 100 but to account for no-responses, a randomly selected sample of 200 institutions that had conducted GHGI was drawn.

3.3. Instrument

Three research methodologies were considered for this project; interviews, survey, and secondary data analysis. Secondary data analysis option was rejected early, on grounds of unavailability of sufficient data. Interviews did not seem suitable either because of the sample size and the number of questions that were required to be addressed. Survey thus was the most appropriate option. A questionnaire was developed, for which approval from the Institutional Review Board (IRB) of Duquesne University was obtained for conducting the survey. The survey was developed on the online survey program Qualtrics, and it was pretested before launching.

3.4. Survey distribution

GHG inventories are conducted by different entities at different institutions. For instance, they can be conducted by the facilities department, sustainability office, faculty, or students. For purposes of this research the most appropriate person to respond to the survey was someone who had either conducted or led the inventory project, or someone who had sufficient knowledge about the institution's inventory. That person, for every institution included in the sample, was sought through information available on the institution's website, inventory reports, other online resources such ACUPCC website, or phone calls.

A request to fill out the survey was sent to the identified individual via an email message that included a link to the online survey. The first page of the survey included the contents of the IRB approved consent form which gave a brief description of the research and the benefits of participation, and asked the respondents to continue only if they were willing to participate in the survey. It also explained that the identity of the respondent will not appear in the data analysis and outcome report, and that responses will only appear in statistical data summaries.

In the email a request was included asking recipient – if they were not the right person to fill out the survey – to recommend someone else from within their institution, who would be able to fill out the survey.

A protocol was established for reaching out to respondents: If a person from an institution did not respond to the first email request, one follow up email was sent. If the person did not respond to that follow-up email either, a phone call was made to him or her. A voicemail was left in situations where a person did not receive the call. No further requests were sent to the respondent after that. With a response rate of approximately 35%, 69 responses were obtained in a timeline of 17 days.

3.5. Data collection

The survey responses were downloaded from Qualtrics into Microsoft Excel. The Excel spreadsheet was then imported into the Statistical Package for the Social Sciences (SPSS) program for statistical analysis.

3.6. Data analysis

This research comprised analyzing the association between different variables. Since the data mostly consisted of categorical variables, the suitable method to test associations was the Chi-Square test. Cross-tabulations between variables were created and Chi-Square tests were run using the SPSS. Because of the small sample size, results for Fisher's Exact Test were used instead of Pearson's Chi-square to test the hypotheses. This is because when the sample size is small the expected counts of the cells in the crosstabs tend to be small which gives inaccurate results for Pearson's Chi-Square test. In such situations, Fisher's Exact Test is more accurate.

Following criteria was used to test the hypotheses (Berman and Wang, 2012).

- If p-value < 0.05, null hypothesis was rejected; a statistically significant relationship was determined.
- If p-value > 0.05, null hypothesis was failed to be rejected; there was not enough statistical evidence to prove a relationship between the two variables.

If a relationship was determined, Cramer's V test was run to measure the strength of association between the two variables. Following scale for Cramer's V test values was used to determine the strength of association (Berman and Wang, 2012).

Values < 0.25 = weak relationship

Values between 0.25 to 0.50 = moderate relationship

Values > 0.50 = strong relationship

Chapter 4: Results

The survey was sent to 200 institutions. A total of 69 (34.5%) institutions responded. However, 7 (3.5%) responses were eliminated from the sample because they were invalid. Among the 7 invalid responses 3 were anonymous, thus their institutional profile information could not be collected, and the other 4 responses had missing answers for a question. Therefore, the final sample comprised 62 responses with a response rate of 31%.

The survey was sent to people who were appropriately relevant to the GHGI of institutions. These personnel held positions in one of the following areas:

1. Administration office
2. Facilities management
3. Sustainability office/committee/council
4. Faculty

In some cases the respondent held two of the above positions; for instance, it was noted that the sustainability positions often overlapped with the remaining 3 positions. To elaborate, in some cases a faculty member was also the chair of the sustainability committee or for that matter, a person from facilities department was also the sustainability coordinator. It was noted among the 200 respondents, 118 (59%) held positions associated with campus sustainability, including sustainability officer, sustainability coordinator, sustainability manager, sustainability committee or council member, sustainability fellow, and so on. The remaining 82 respondents did not hold sustainability related positions. To assess the response numbers of sustainability associated personnel versus those not associated with campus sustainability a cross table was created (See Table 1).

Table 1

Response status of sustainability associated and non-associated personnel

	Sustainability Associated		Sustainability non-associated		
Response status	Number	Column percentage	Number	Column percentage	Total
Responded	48	41.38%	14	17.50%	62
Not responded	68	58.62%	66	82.50%	134
Total	116	100%	80	100%	196

Note. The survey did not include any question about the respondent's position. This information was obtained from a record of the people the survey was being sent to. 69 responses came in however in this table the total for "responded" is 66. This is because 3 (out of 69) responses were anonymous and thus could not be identified and excluded from the list. Therefore, they are counted under the "not-responded" category.

Table 1 shows a comparison of response status for both sustainability associated and sustainability non-associated categories. It can be noted that the percentage of responses (within category) obtained from sustainability associated personnel (41.38%) is greater than those of obtained from sustainability non-associated personnel (17.50%). In cases of people who did not respond to the survey the percentage of sustainability non-associated people (82.50%) was greater than that of sustainability associated (58.62%). However, it can also be noted that within categories of both sustainability associated and sustainability non-associated people, the percentages of non-responses (58.62% and 82.50% respectively) were greater than that of responses (41.38% and 17.50% respectively).

4.1. Sample description

The 62 responses came from 28 different states of the country. So, the sample does not represent all the states of the country. Table 2 shows the distribution of respondents over the geographical regions.

Table 2

Geographic representation of responses

No.	Geographic region	Responses	Percentage
1	New England	5	8.06
2	Great Lakes	8	12.9
3	Southeast	9	14.52
4	Rocky Mountains	1	1.61
5	Mideast	15	24.19
6	Plains	5	8.06
7	Southwest	3	4.84
8	Far West	16	25.81
	Total	62	100

Note. The geographical region categories used in this table were obtained from the report "Climate change leadership in higher education institutions" (Association of Climate Change Officers, 2011). (See footnote[1] for specification of states within every region)

In Table 2 it can be noted that at least one or more responses were collected from all 8 geographical regions. Thus, the sample was representative of all geographic regions. The greatest number of responses came from the Far West region (16) and lowest number from Rocky Mountains (1).

[1] New England: CT, ME, MA, NH, RI, VT Great Lakes: IL, IN, MI, OH, WI Southeast: AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, WV Rocky Mountains: CO, ID, MT, UT, WY Mid East: DE, DC, MD, NJ, NY, PA Plains: IA, KS, MN, MO, NE, ND, SD Southwest: AZ, NM, OK, TX Far West: AK, CA, HI, NV, OR, WA

Institutional profile information of the respondents was collected using the Carnegie Classification of Institutions of Higher Education (The Carnegie Classification of Institutions of Higher Education, n.d.). This information comprised institution type, level, size, and residential status.

As shown in Figure 1 the majority (43) of institutions in the sample were public as opposed to private (19). Thus, this sample is not a very good representative of private institutions.

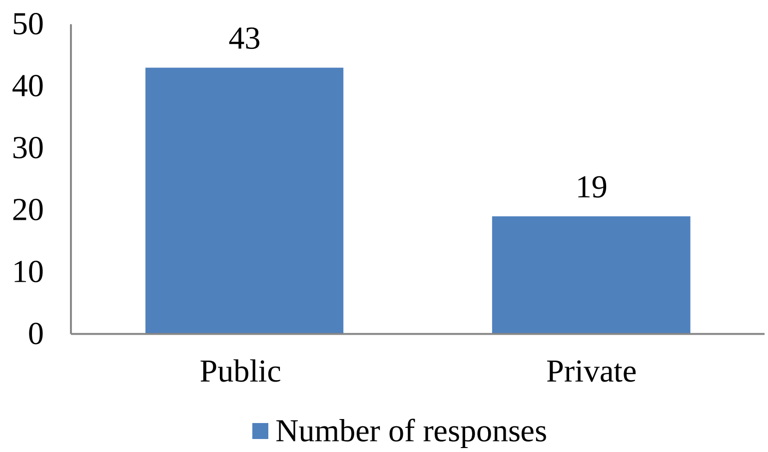

Figure 1: Frequency of public and private institutions

Figure 2 shows that a majority (46) of the institutions included in this sample were 4-year institutions and a minority (16) was 2-year institutions. Therefore, this sample is not a good representative of 2-year institutions.

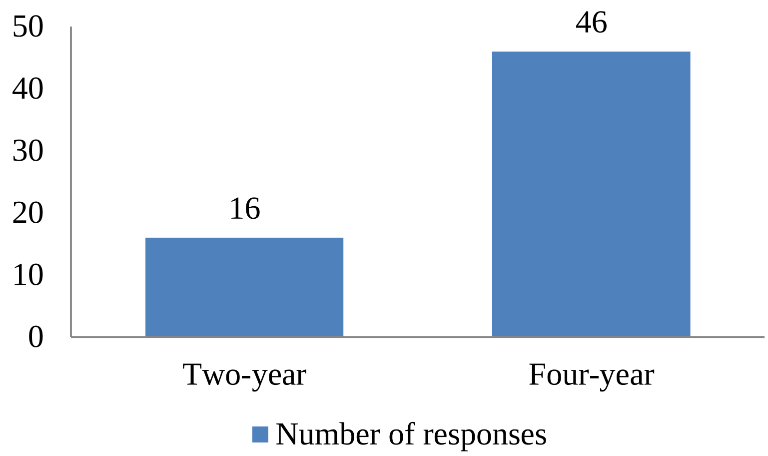

Figure 2: Frequency of 2-year and 4-year institutions

Respondents were also categorized into small, medium, and large categories. Institutions that were not listed in one of these 3 categories in Carnegie Classification were listed under the “other” category. Figure 3 illustrates a breakdown of the respondent institutions by their sizes.

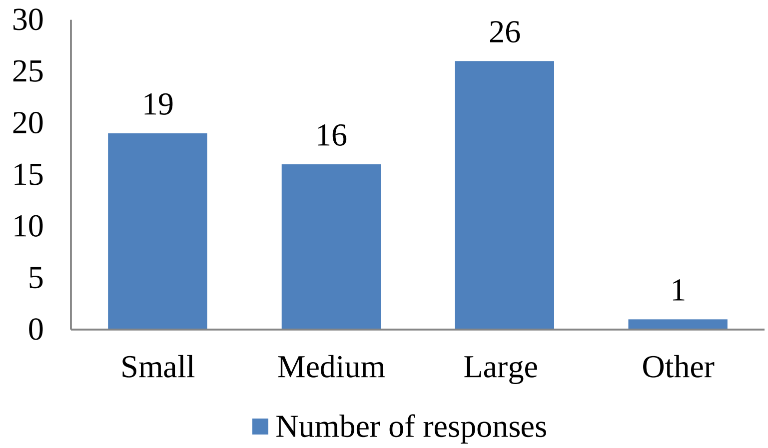

Figure 3: Sizes of the respondent institutions

It can be seen in Figure 3 the highest number of responses (26) came from large institutions, followed by small institutions (19), and the lowest number (16) came from medium sized institutions.

Respondents were also categorized into residential and non-residential using the Carnegie Classification (See Figure 4). It is to be noted here that the “primarily residential” and “highly residential” categories were merged into residential in this study. The institutions that did not have a classification for residential status were listed as “other”.

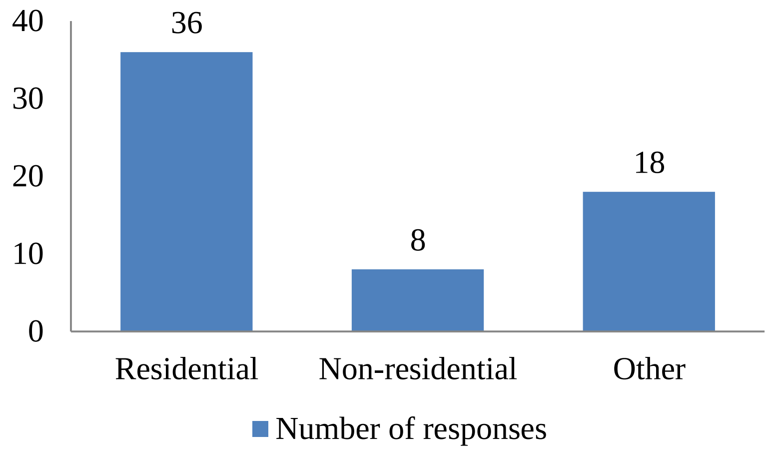

Figure 4: Residential and non-residential status of the institutions

Figure 4 indicates that the majority of the institutions (36) in this study were residential and only a few were non-residential (8).

Information about the community setting of the institutions was also collected from 3 web sources ACUPCC, U.S. News & World Report – Education, and Campus explorer. Institutions were listed as urban, suburban, or rural. (See Figure 5)

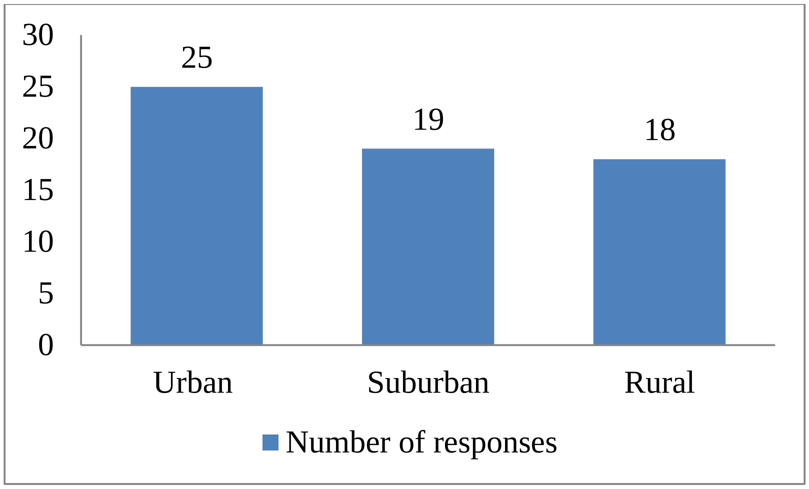

Figure 5: Community settings of the respondents

80.6% of the institutions (25) were situated in an urban setting and a fairly equal number of institutions were located in suburban and rural settings (19 and 18, respectively).

It was also of interest – for the assessment of other variables that will be discussed later – to determine if the respondent institution had a sustainability entity. A sustainability entity for the purpose of this study refers to any of the following:

1. Sustainability office
2. Sustainability institute
3. Sustainability director, manager, coordinator, officer, fellow, or so on.
4. Sustainability committee or council.

This information was collected through websites of institutions, ACUPCC, and AASHE. Figure 6 shows the number of institutions that had and not had sustainability entity.

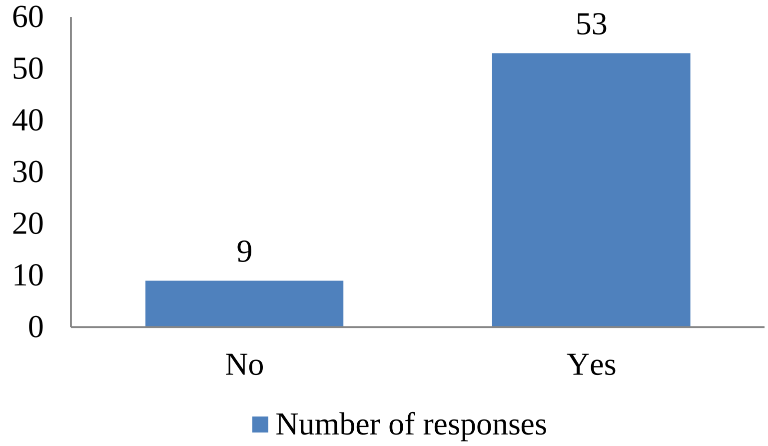

Figure 6: Presence of a sustainability entity in the institutions

As seen in Figure 6 a clear majority of the respondents (53) had a sustainability entity on their campus. Only a few (9) institutions did not have any type of sustainability related office or position.

4.2. Entities involved in the decision to conduct GHGI

A question was asked in the survey: Who, at your institution, decided to create a GHGI? It was asked as a multiple response question because at times multiple entities are involved in the decision-making process. Therefore, the response categories were not mutually exclusive. The survey responses indicated in many cases more than one entity participated in the decision making process. The response frequency for every entity is given in Table 3.

Table 3

Participation of institutional entities in decision making

Entity	Involved	Not involved	Total
President/Chancellor	30	32	62
Administration/Facilities	22	40	62
Sustainability office/committee	31	31	62
Faculty	13	49	62
Student	6	56	62

As demonstrated by Table 3 sustainability office/committee was involved in decision-making in the highest number of cases (31), very closely followed by president/chancellor (30). Administration or facilities department was also involved in a significant number of cases (22). Fewer respondents indicated the participation of faculty (13) or student (6). It is important to mention here that the sustainability office at some institutions is a part of the facilities department. Therefore, it is likely that respondents who selected the “sustainability office” response also selected “facilities department”.

The survey responses were further analyzed to test for an association between the presence of the sustainability office/entity at institutions and the involvement of sustainability office/committee in deciding to conduct the GHGI. A crosstab of the two variables is given in Table 4.

Table 4

Crosstab: presence of sustainability entity and participation in decision-making

		Presence of a sustainability entity		
		No	Yes	Total
Participation in decision-making	No	8	23	31
		25.8%	74.2%	100%
	Yes	1	30	31
		3.2%	96.8%	100%
Total		9	53	62
		14.5%	85.5%	100%

Chi-square tests were conducted using SPSS (See Appendix C). Since 50% of cells had expected count of less than 5, Pearson Chi-square could not be used because of the violation of its assumption. Therefore, Fisher's exact test result was used instead. Exact significance (2-sided) of 0.026 was obtained, which is less than 0.05; thus, the null hypothesis was rejected and a statistically significant association was found to exist between the presence of a sustainability entity and its involvement in deciding to conduct a GHGI. The strength of association was ascertained using the Cramer V test (See Appendix D). A Cramer's value of 0.321 showed a moderate association. As evident in Table 4, in the presence of a sustainability office, it was more likely for it to participate in the decision-making as opposed to not participating.

4.3. Entities involved in conducting the GHGI

Another question in the survey was; who conducted the GHGI of your institution? While reading the GHGI reports of the institutions, during the literature review stage, it was noted that often more than one entity was involved in conducting the inventory. Therefore, the respondents were given multiple response options in the survey comprising facilities department, sustainability office, faculty, student, and consultant. The response frequencies are given in the Table 5.

Table 5

Participation of institutional entities in conducting GHGI

Entity	Involved	Not involved	Total
Facilities department	27	35	62
Sustainability office	31	31	62
Faculty	12	52	62
Student	20	42	62
Consultant	8	54	62

It was observed (See Table 5) that sustainability office was involved in conducting the GHGI in most number of cases (31), followed by facilities department (27). Students also participated in conducting the GHGI in a significant number of cases (20). Faculty and consultant were involved in conducting the GHGI in the lowest number of cases (12 and 8 respectively).

From the GHGI reports read on the ACUPCC website it was observed that in many institutions the sustainability office conducted the GHGI. Therefore, it was believed if an institution had a sustainability office, it will be likely to participate in conducting the GHGI. To test this hypothesis, an associational analysis between the presence of a sustainability entity at institutions and the involvement of the sustainability office (or entity) in conducting the GHGI was conducted. Table 6 shows a crosstab of the two variables.

Table 6

Crosstab: presence of sustainability entity and participation in conducting GHGI

		Presence of sustainability entity		
		No	Yes	Total
Participation in conducting GHGI	No	9	22	31
		29.0%	71.0%	100%
	Yes	0	31	31
		0.0%	100%	100%
Total		9	53	62
		14.5%	85.5%	100%

In Table 6 it can be noted that if an institution had a sustainability entity there were more chances of it conducting the GHGI than that of not conducting the GHGI. The observed association was confirmed to be statistically significant through Fisher's exact test; whereby an exact significance (2-sided) value of 0.002 was obtained (See Appendix C). A Cramer's V test value of 0.412 showed the association to be moderately strong (See Appendix D).

4.4. Did GHGI require finances?

The campus carbon calculation tool that ACUPCC recommends to use is available for free. If institutions use the free tool and assign the task of conducting the GHGI to the staff, faculty, or student for that matter the inventory should typically cost nothing. However, to figure out if the institutions are conducting GHGI for free or not, the respondents were asked if their GHGI incurred any costs? The results are given in Table 7.

Table 7

Finances of conducting the GHGI

Cost sources	Responses	Percentage
Consultant	10	16.1
Student	6	9.7
Tool	3	4.8
No costs	36	58.1
Other	7	11.3
Total	62	100

Results (See Table 7) indicate that the majority of the institutions (36) reported that conducting the GHGI did not cost anything. A total of 19 institutions reported that finances were required; these included paying the consultant (10) hired for conducting the GHGI, paying stipend to a student (6) who conducted the GHGI, and cost of the purchased tool (3) used for calculating GHG emissions. The remaining 7 institutions in the sample selected the “other” option, which can imply different meanings; for instance, any other cost options not were not listed in the response categories, or may be the respondent did not know about the finances of the GHGI.

Figure 7 shows a distribution of responses by the incurred finances of GHGI at institutions.

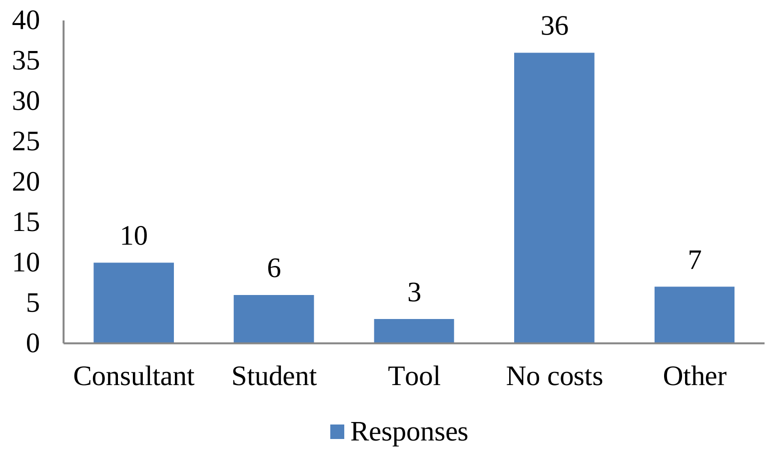

Figure 7: Finances of conducting the GHGI

4.5. Climate change mitigation within institutions

The respondents were asked if their institution had taken any measures to reduce their institution's GHG emissions. Out of the 62 responses, except 1 response that indicated no measures all the respondents reported their institution had taken measures to reduce GHG emissions. The respondents were not asked to list the measures they had taken; however, information from the university and ACUPCC websites indicates the measures mostly comprise: energy conservation projects such as energy efficient retrofitting, using renewable energy sources, promoting use of public transportation, reducing campus waste generation, and so on.

The respondents were also asked to give an estimate of the reduction in their institution's GHG emissions within the last decade. The responses were distributed in 2 categories: 10% and below and above 10% reduction in GHG emissions. A greater number of institutions (33) reported 10% and below reductions and a smaller number (29) reported above 10% reductions (See Table 8).

Table 8

Estimated percentage of emissions reduced

Estimated percentage reduction	Responses	Percentage
10% and below	33	53.2
Above 10%	29	46.8
Total	62	100

It is important to mention here that several factors come into play when comparisons of GHG emission trends are drawn among IHE; including geographic region, demographics, climate, budget and resources, institution size, research activity, residential setting, community setting, and so forth. On the ACUPCC website also it was suggested to take caution while making comparisons between IHE.

In this research the association of a few of these factors with the emission reductions was analyzed. The estimated emission reductions were analyzed against the following variables:

1. Presence of a sustainability entity within institution
2. Institution type
3. Institution level
4. Community setting

Table 9 shows a crosstab of estimated reduction in emissions and the presence of a sustainability entity within institutions. The emissions reduction does not seem to vary in association with the existence of a sustainability entity. Fisher's exact test did not prove any statistically significant association either. (See Appendix C)

Table 9

Crosstab: estimated reduction in emissions and presence of sustainability entity

		Estimated percentage of emissions reduced		
		10% and below	Above 10%	Total
Presence of sustainability entity	No	5	4	9
		55.6%	44.4%	100%
	Yes	28	25	53
		52.8%	47.2%	100%
Total		33	29	62
		53.2%	46.8%	100%

Table 10 shows a crosstab of estimated reduction in emissions and the institution type. It can be observed that the public institutions are more likely to have lower emission reductions (10% and below) whereas private institutions were more likely to have higher emission reductions (above 10%). The association was also confirmed using Fisher's exact test results (See Appendix C) With an exact significance (2-sided) value of 0.006 (which is lesser than 0.05) the null hypothesis was rejected and a statistically significant association was evident.

Table 10

Crosstab: estimated reduction in emissions and institution type

		Estimated percentage of emissions reduced		
		10% and below	Above 10%	Total
Institution type	Public	28	15	43
		65.1%	34.9%	100%
	Private	5	14	19
		26.3%	73.7%	100%
Total		33	29	62
		53.2%	46.8%	100%

The estimated reduction in emissions and the institution type were found to be moderately associated through a Cramer's V value of 0.359 (See Appendix D).

The estimated reduction in emissions was also cross tabulated with the institution level (See Table 11). The 4-year institutions were more likely to have higher emission reductions (above 10%) and 2-year institutions were more likely to have lower emission reductions (10% and below).

Table 11

Crosstab: estimated reduction in emissions and institution level

		Estimated percentage of emissions reduced		
		10% and below	Above 10%	Total
Institution level	2-year	14	2	16
		87.5%	12.5%	100%
	4-year	19	27	46
		41.3%	58.7%	100%
Total		33	29	62
		53.2%	46.8%	100%

To test the observed association statistically, Fisher's exact test was conducted. An exact significance (2-sided) value of 0.001 was obtained (See Appendix C). Thus the null hypothesis was rejected and enough statistical evidence was found to prove a significant association between the estimated reduction in emissions and the institution level. Cramer's V value of 0.405 showed the association to be moderate. (See Appendix D)

The estimated emission reduction was also analyzed against the community setting in which the institution was located. Table 12 shows a crosstab between the two variables. It can be noted that though urban and suburban institutions seem to have lower emission reduction and rural institutions seem to have higher emission reductions, however this pattern is not very striking. To statistically check the observation Pearson

Chi-square test was used.[2] An asymptotic significance value of 0.6 was obtained which is greater than 0.05, thus the null hypothesis was failed to be rejected (See Appendix C).

Table 12

Crosstab: estimated reduction in emissions and community setting

		Estimated percentage of emissions reduced		
		10% and below	Above 10%	Total
Community setting	Urban	15	10	25
		60.0%	40.0%	100%
	Suburban	10	9	19
		52.6%	47.4%	100%
	Rural	8	10	18
		44.4%	55.6%	100%
Total		33	29	62
		53.2%	46.8%	100%

4.6. Use of GHGI for climate change mitigation within institutions

In the literature review it was pointed out that the purpose of the GHGI is to generate baseline information of the GHG emissions. This information is useful for climate change mitigation because it can facilitate mitigation action in two main ways:

1. Informing decisions regarding emission reduction measures.
2. Helping in forming either a climate action plan (CAP), or a sustainability policy (SP).

To assess if institutions were finding the GHGI helpful in the above mentioned ways, they were asked two questions:

[2] Fisher's exact test could not be used because community setting had 3 categories.

1. Did your GHGI facilitate decision making regarding which emission reduction measures to take?
2. Did your institution use its GHGI to form the CAP or SP?

The results are assessed in the following sections.

4.6.1. Use of GHGI in making decisions

Table 13 indicates how helpful the GHGI were in making decisions regarding which emission measures to implement.

Table 13

GHGI's effectiveness in informing decisions

Response	Frequency	%
didn't use	14	22.6
not helpful	2	3.2
slightly helpful	23	37.1
very helpful	23	37.1
Total	62	100

The majority of the institutions (46) found GHGI to be either slightly, or very helpful and only 2 institutions did not find them helpful. Among the remaining responses 14 institutions did not use their GHGI to inform decisions.

It was hypothesized earlier in the study that the use of the GHGI in decision making was associated with the GHG emission reduction within institutions. To test this hypothesis the variable "estimated reduction in emissions" was cross-tabulated with the "GHGI's effectiveness in informing decisions" (See Table 14). To use Fishers' exact test, the responses for GHGI's effectiveness in emission reduction were collapsed into 2 categories; the "very helpful" category remained the same, while the other 3 categories (did not use, not helpful, and slightly helpful) were collapsed into a single category named "not very helpful". The crosstab (Table 14) between the two variables shows that when the GHGI was found very helpful there were more chances of higher emission reductions (above 10%) and when the GHGI was not found very helpful there were more chances of lower reductions (10% and below). However, the Fisher's exact test (See Appendix C) resulted in an exact significance (2-sided) value of 0.116 and thus the null hypothesis was failed to be rejected on the basis that there was not enough statistical evidence to prove the association between the two variables. It is recommended to use a larger sample to test this hypothesis in future studies.

Table 14

Crosstab: estimated reduction in emissions and GHGI's effectiveness in informing decisions

		Estimated percentage of emissions reduced		
		10% and below	Above 10%	Total
GHGI's effectiveness in informing decisions	Not very helpful	24	15	39
		61.5%	38.5%	100%
	Very helpful	9	14	23
		39.1%	60.9%	100%
Total		33	29	62
		53.2%	46.8%	100%

It was believed that if the GHGI was conducted by the facilities department or the sustainability office there were more chances that the GHGI will be used more effectively in the decision making process. This is because these entities are typically actively involved in the decisions regarding the campus operations. Therefore an associational analysis of the use of GHGI in decision making was conducted with the following variables:

1. Presence of a sustainability entity at institution
2. Participation of facilities department in conducting the GHGI
3. Participation of sustainability office in conducting the GHGI

Fisher's exact tests results revealed that none of these 3 variables were significantly associated with the effectiveness of GHGI in decision making. (See Appendix C for cross tabs and Fisher's exact test details)

4.6.2. Use of GHGI in forming a CAP/SP

The survey asked if the institution had either a CAP or SP. A clear majority (54) of institutions responded in positive and only 8 institutions did have neither a CAP nor SP. The respondents were then asked to state the extent to which the GHGI was used in forming the CAP or SP. Responses are summarized in Table 15.

Table 15

GHGI's use in CAP/SP

Response	Frequency	%
used to a significant extent	32	51.6
used to a small extent	17	27.4
not used at all	6	9.7
don't have a CAP/SP	7	11.3
Total	62	100

As shown in Table 15, a majority of the respondents (49) did make use of the GHGI in forming a CAP or SP and among them, 32 used it to a significant extent and 17 used it to a small extent. A few (6) institutions did not use it in forming a CAP or SP and a few (7) did not have a CAP/SP.

The responses for this question were collapsed into 2 categories for further associational analysis with other variables. The “used to a significant extent” category remained the same while the rest of the categories were merged into a single category called “not used significantly”.

The second hypothesis formed during the earlier part of the study stated that the use of the GHGI in forming a CAP was associated with GHG emission reduction within institutions. A crosstab was created between the two variables (See Table 16) and statistical tests were conducted. Table --- shows that when the GHGI was used significantly it was more likely to have higher emission reductions (above 10%) and when the GHGI was used not significantly it was more likely to have lower reductions (10% and below).

Table 16

Crosstab: estimated reduction in emissions and GHGI’s use in forming CAP/SP

		Estimated percentage of emissions reduced		
		10% and below	Above 10%	Total
GHGI’s use in CAP/SP	Used significantly	13	19	32
		40.6%	59.4%	100%
	Not used significantly	20	10	30
		66.7%	33.3%	100%
Total		33	29	62
		53.2%	46.8%	100%

The exact significance (2-sided) value of Fisher's exact test was less than the p-value (i.e. 0.047 < 0.05), therefore the null hypothesis was rejected (See Appendix C). Thus the hypothesis that the GHG emission reduction was associated with the use of GHGI in CAP was proved true. The Cramer's V test result showed that there was a moderate association between the two variables. (See Appendix D)

The use of GHGI in forming a CAP/SP was also analyzed against 3 other variables including; presence of a sustainability entity at an institution, participation of sustainability entity in conducting the GHGI, and participation of facilities department in conducting the GHGI. No statistically significant association was found between the use of GHGI in forming CAP/SP and the first and second variable; however a statistically significant association was found with third variable. Table 17 shows a crosstab between the use of GHGI in CAP/SP formation and participation of facilities department in conducting GHGI.

Table 17

Crosstab: participation of facilities department in conducting GHGI and GHGI's use in forming CAP/SP

		Participation of facilities department		
		No	Yes	Total
GHGI's use in CAP/SP	Used significantly	13	19	32
		40.6%	59.4%	100%
	Not used significantly	22	8	30
		73.3%	26.7%	100%
Total		35	27	62
		56.5%	43.5%	100%

In Table 17 it can be observed that if the facilities department participated in conducting the GHGI, the GHGI was more likely to be used significantly in climate action planning. On the other hand, if the facilities department did not participate in conducting the GHGI it was less likely to be used significantly. The Fisher's exact test result (See Appendix C) also reveals that there is enough statistical evidence to prove a significant association. Cramer's V test indicates the association is moderate. (See Appendix D)

4.7. Uses of GHGI

During the literature review, five main areas were identified where a GHG inventory can be of use to IHE. These uses were assessed through the survey as well. The respondents were asked if their institution's GHGI helped them with the following:

1. Identifying sources & quantifying emissions
2. Savings costs
3. Monitoring progress of emissions reduction
4. Raising climate change awareness
5. Using the GHG inventory for pedagogical purposes

Table 18 displays the responses for the uses of GHGI. A majority of the respondents (48) found the GHGI significantly helpful in identifying the sources and quantifying the GHG emissions. In a majority of the responses (45) the GHGI was found helpful in saving costs by facilitating the identification of suitable mitigation options. In most of the cases the GHGI helped in monitoring the progress of GHG emission reduction (58) as well as raising climate change awareness at institutions (55). Respondents were also asked if the inventory was found useful for teaching purposes;

though most of the respondents (42) reported it to be helpful there was a significant number (20) that did not find it helpful for this purpose.

Table 18

Responses for the uses of GHGI

No.	Uses	Not helpful	Slightly helpful	Significantly helpful	Total
1	Identifying sources & quantifying emissions	2	12	48	62
		3%	19%	77%	100%
2	Savings costs	17	31	14	62
		27%	0.5	23%	100%
3	Monitoring progress of emissions reduction	4	24	34	62
		6%	39%	55%	100%
4	Raising climate change awareness	7	34	21	62
		11%	55%	34%	100%
5	Pedagogical purposes	20	29	13	62
		32%	47%	21%	100%

Figure 8 displays a distribution of responses for the uses of the GHGI.

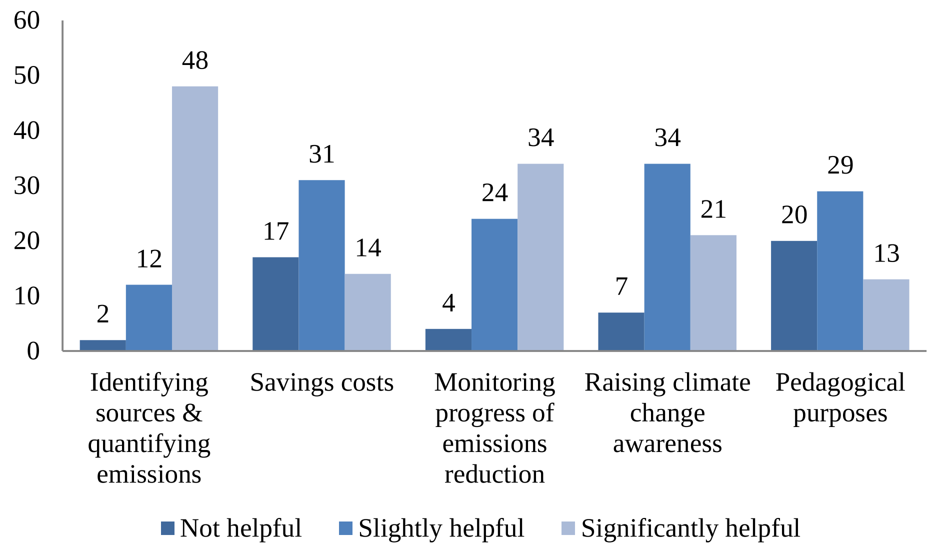

Figure 8: Responses for the uses of GHGI

GHGI reports of institutions often state that the inventory was conducted to determine the baseline of GHG emissions for planning mitigation action, and to keep track of emission reductions. Because of these literature findings, it was of interest to test if there was an association between the use of GHGI in climate action planning and – GHGI's help in identifying sources and quantifying emissions, and GHGI's help in monitoring progress of emission reductions. The associational analysis is discussed as follows.

Table 19 shows a crosstab of variable identifying sources and quantifying emissions with the GHGI's use in CAP/SP. The crosstab indicates that if the GHGI was found significantly helpful in identifying sources and quantifying emissions, it was more likely to be significantly used in climate action planning. However, if the GHGI was not found significantly helpful in identifying and quantifying emissions, it was more likely to be not used significantly in forming a CAP.

Table 19

Crosstab: GHGI's use in CAP/SP and identifying sources & quantifying emissions

		GHGI's use in CAP/SP		
		Used significantly	Not used significantly	Total
Identifying sources & quantifying emissions	Helped significantly	31	17	48
		64.6%	35.4%	100%
	Not helped significantly	1	13	14
		7.1%	92.9%	100%
Total		32	30	62
		51.6%	48.4%	100%

An exact significance value of 0.000 obtained through Fisher's exact test (See Appendix C) confirmed that the association between the effectiveness of GHGI in identifying sources and quantifying emissions, and GHGI's use in CAP/SP was statistically significant. The strength of the association was moderate as shown by Cramer's V value of 0.481. (See Appendix D)

GHGI's help in monitoring progress of emission reductions was cross tabulated with the GHGI's use in CAP/SP, as shown in Table 20. It shows that if the GHGI significantly helped in monitoring the progress of emission reductions, there were more chances of it being used significantly in forming CAP/SP; whereas, if the GHGI did not help significantly, there were more chances of it being not used significantly.

Table 20

Crosstab: GHGI's use in CAP/SP and monitoring progress of emission reductions

		GHGI's use in CAP/SP		
		Used significantly	Not used significantly	Total
Monitoring progress of emission reductions	Helped significantly	26	8	34
		76.5%	23.5%	100%
	Not helped significantly	6	22	28
		21.4%	78.6%	100%
Total		32	30	62
		51.6%	48.4%	100%

The Fisher's exact test results also confirmed the existence of a statistically significant association between the two variables (See Appendix C). A Cramer's V value of 0.548 stated the ascertained the association to be strong. (See Appendix D)

Two more variables were expected to have an association – GHGI's facilitation in saving costs through identification of suitable mitigation measures and the use of GHGI in making decisions regarding emission reduction measures. Table 21 shows the crosstab of the two variables. It was observed that if the GHGI significantly helped in savings costs it was more likely to be very helpful in informing decision regarding emission reduction measures. Similarly, if the GHGI did not significantly help in savings costs it was more likely to be not very helpful in informing decisions either.

Table 21

Crosstab: GHGI's effectiveness in informing decisions and GHGI's facilitation in saving costs

		GHGI's effectiveness in informing decisions		
		Not very helpful	Very helpful	Total
GHGI's facilitation in saving costs	Helped significantly	5	9	14
		35.7%	64.3%	100%
	Not helped significantly	34	14	48
		70.8%	29.2%	100%
Total		39	23	62
		62.9%	37.1%	100%

The observed association was found to be statistically significant through Fisher's exact test results; exact significance value was 0.027 (< 0.05), thus null hypothesis was rejected (See Appendix C). The strength of association was found to be moderate (See Appendix D).

Chapter 5: Discussion

5.1. Research findings

This study focused on the IHE because of their leadership role in tackling the climate change challenge. IHE – by reducing their GHG emissions and by educating stakeholders about climate change – can be instrumental in the transition towards a more sustainable society (Zhaurova, 2008; Hale, 2007; Rappaport & Creighton, 2007; Knuth et al., 2007). In this research, the sample for survey was drawn from 3 sources – ACUPCC, AASHE – STARS program, and EPA-ENERGY STAR. Since, all the respondents were committed to at least one of these 3 voluntary programs, the sample is not representative of the institutions that are not members of these programs.

It is recommendable to join a voluntary program because these programs inspire action and also provide a forum for exchange of ideas, information, and success stories (Hale, 2007; Velazquez et al., 2006). However, it has also been said that signing these commitments is not very effective when support of administrative leadership is lacking (Association of Climate Change Officers, 2011). One study conducted at the University of Massachusetts Amherst, had stated in its recommendations that the university should urge for appointing a chancellor who is devoted to the responsibility towards climate change (Hale, 2007).

It has been observed that many institutions that are signatories to sustainability declarations lack in implementation of their commitments, which research suggests is probably because these pledges have no binding force or legal enforcement (Association of Climate Change Officers, 2011; Bekessy, et al., 2007).

All the respondents to this survey had conducted at least one GHGI. Therefore, the sample does not represent the institutions that have not performed the inventory. However, the information obtained from the findings of this research can be relevant to any IHE that intends to act towards climate change mitigation and wants to reduce its emissions.

The response rate for the survey was 31%. It was observed that among the respondents, a number of responses came from personnel who held sustainability related positions within the institution. Among the people who did not respond to the survey, more of them did not hold a sustainability associated position. It implies that people who were involved in campus sustainability activities were more willing to talk about their institution's GHGI than those who were not. This could be due to different reasons, for instance they were better aware of their inventories, or they were more interested in the topic.

The survey helped in assessing the role of GHGI within institutions. It was ascertained that a majority of the respondents (74%) found GHGI helpful in informing decisions regarding emission reduction measures. This finding was in line with the inference withdrawn from literature that GHGI facilitated decision making by spotting chief emitters and identifying energy conservation options. (Moerschbaecher & Day Jr. 2010; Zhaurova, 2008; Thurston & Eckelman, 2011; Eagan, 2008).

87% of respondents had formed a CAP or SP. This was probably because majority of the respondents were signatories of ACUPCC, and hence, were bound by pledge to form a CAP. The results were compared with another relevant survey-based study "Climate change leadership in higher education institutions" and an interesting similarity was found in results: In that study 51% of its respondents had a CAP in place and 35% were in the process of developing one, summing up the two comes out to be 86% which is very close to our findings. That study also reported: in cases when the president of the institution oversaw the institution's climate change related action, 96% of them had formed a CAP; when a committee or similar entity was responsible, 68% had a CAP; and in the absence of a responsible entity, 28% had a CAP. (Association of Climate Change Officers, 2011). Forming a CAP typically does not cost anything, especially if it is developed by the institution's staff. Sustainability coordinators are said to be appropriate for conducting the planning process (Kinsley & DeLeon, 2009).

GHGI can be used as an instrument for setting goal, and framing strategies and policies. Hence, it is referred to as the first step in climate action planning (Klein-Banai et al., 2010; Hale, 2007; Eagan, 2008; Zhaurova, 2008). Survey results showed around 79% of the survey respondents made use of GHGI in forming climate action plans or policies. The survey did not ask if the CAPs were successfully implemented or not. However, during analysis of results, the association between the use of GHGI in CAP formation and the emissions reduced was tested through Fisher's exact test. A statistically significant association was found between the two variables. When the GHGI was used significantly it was more likely to have higher emission reductions (above 10%) and when the GHGI was not used significantly it was more likely to have lower reductions (10% and below).

It was noted when the facilities department was involved in conducting the GHGI it was more likely to be used significantly in CAP formation. This made sense – since the facilities department controls all the campus operations, it is well suited to use the inventory information in planning to operate the campus more sustainably.

On the other hand, involvement of the sustainability office in conducting inventory did not have any statistically significant association with the use of inventory in CAP. This was contrary to expectation. The sustainability office or committee typically assists in developing strategies and policies, and participates in making decisions (Velazquez et al., 2006). Thereby, there was an expectation that if the sustainability office performs the inventory it will likely be used for planning. The main responsibilities of a sustainability entity include; organizing efforts, distributing information, and monitoring implementation and progress (Velazquez et al., 2006). Institutions are growingly realizing the importance of having an entity entirely dedicated to climate change and other sustainability related responsibilities. For instance, one survey report comprising 160 responses showed that 75% of responding institutions had made changes in organizational structure to create positions for climate change related tasks (Association of Climate Change Officers, 2011). University of Illinois reported revival of an inert sustainability movement upon the establishment of a “Campus Sustainability Task Force” (Klein-Banai et al., 2010).

5.2. Limitations of the study

One limitation of this study was a small sample size i.e. 200 institutions, which represent only around 2.8% of more than 7000 IHE within the country. With a small response rate (31% of 200), the surveyed sample was less than 1% of all the institutions; thus, the sample was not a good representation of all IHE in the country.

The survey sample was drawn from 3 sources – ACUPCC, AASHE – STARS program, and EPA – ENERGY STAR. Since all the respondents had signed up for at least one of these commitments, this limits the representativeness of the sample to only those institutions that have signed up for these programs. About 95% of the responding institutions had signed the ACUPCC pledge. ACUPCC lays out some guiding steps towards achieving carbon neutrality which include conducting GHGI and forming CAP. Thus commonalities can be expected to exist in the way all the signatory institutions work towards climate commitment, which in turn could possibly have influenced the research findings. For instance, this can explain why a majority of the institutions had a CAP in place. However, this does not reduce the relevance of the research findings to institutions that are not ACUPCC members because the way the GHGI were used, the factors involved, and the associated emission reduction provides information that can be used by institution of higher education. In short, the study might not be representative of non-signatory institutions but the findings can surely be used by any institution.

Chapter 6: Conclusion

6.1. Summary

This study builds on prior research on climate change initiatives within IHE with a focus on GHGI. A survey methodology provides the primary data utilized for analysis and insight. The survey was emailed to 200 institutions of higher education. It was noted that the percentage of responses obtained from sustainability associated personnel (41.38%) was greater than those of obtained from sustainability non-associated personnel (17.50%). In cases of people who did not respond to the survey the percentage of sustainability non-associated people (82.50%) was greater than that of sustainability associated (58.62%).

A sample of 62 responding institutions was analyzed to assess the role of GHGI in climate change mitigation within IHE. Responses came in from 28 different states of the country. Institutional profile of respondents was assessed and it was found the majority of institutions were public, four-year, large-sized, residential, and urban. 53 of the 62 institutions had an entity in place for sustainability.

The highest number of institutions reported the decision to conduct the GHGI was made by the sustainability entity (31), very closely followed by the President (30). A statistically significant association was found to exist between the presence of a sustainability entity and its involvement in deciding to conduct a GHGI. Survey results also showed that sustainability office was involved in conducting the GHGI in most number of cases (31), followed by facilities department (27). It was also noted that if an institution had a sustainability entity it was more likely to be involved in conducting the GHGI.

Majority of the institutions (36) reported that conducting the GHGI did not cost anything. 61 out of 62 respondents indicated they had taken measures to reduce emissions. A greater number of institutions (33) reported 10% and below reductions in their GHG emissions and a smaller number (29) reported above 10% reductions. The estimated emission reductions were analyzed against 4 variables; the presence of a sustainability office, institution type, institution level, and community setting. A statistically significant association was found with 2 of these 4 variables – institution type and level. It was observed that the public institutions were more likely to have lower emission reductions (10% and below) whereas private institutions were more likely to have higher emission reductions (above 10%). The 4-year institutions were more likely to have higher emission reductions (above 10%) and 2-year institutions were more likely to have lower emission reductions (10% and below).

A majority of the institutions (46) found GHGI to be helpful. The first hypothesis of this research was that the use of GHGI in informing decisions was associated with the GHG emissions reduced within institutions of higher education. Fisher's exact test results proved this hypothesis to be not true. The use of GHGI in decision making was also tested with other variables including; presence of a sustainability entity at institution, participation of facilities department in conducting the GHGI, and participation of sustainability office in conducting the GHGI. Fisher's exact tests results revealed that none of these 3 variables were significantly associated with the use of GHGI in decision making.

Among the 62 respondents, 54 reported they had a CAP/SP in place. A majority of the respondents (49) did make use of the GHGI in forming the CAP /SP, and among them 32 used it to a significant extent and 17 used it to a small extent. The second hypothesis stated that the use of the GHGI in forming a CAP was associated with GHG emission reduction within institutions. Results of Fisher's exact test proved it to be true; when the GHGI was used significantly it was more likely to have higher emission reductions (above 10%) and when the GHGI was used not significantly it was more likely to have lower reductions (10% and below). The use of GHGI in forming a CAP/SP was also analyzed against 3 other variables including; presence of a sustainability entity at an institution, participation of sustainability entity in conducting the GHGI, and participation of facilities department in conducting the GHGI. A statistically significant association was found to exist with the third variable only. It was observed that if the facilities department participated in conducting the GHGI, the GHGI was more likely to be used significantly in climate action planning. On the other hand, if the facilities department did not participate in conducting the GHGI it was less likely to be used significantly.

A majority of the respondents (48) found the GHGI significantly helpful in identifying the sources and quantifying the GHG emissions. In a large number of responses (45) the GHGI was found helpful in saving costs by facilitating the identification of suitable mitigation options. In most of the cases the GHGI helped in monitoring the progress of GHG emission reduction (58) as well as raising climate change awareness at institutions (55). Respondents were also asked if the inventory was found useful for teaching purposes; though most of the respondents (42) reported it to be helpful there was a significant number (20) that did not find it helpful for this purpose.

The two variables – GHGI's help in identifying sources and quantifying emissions, and GHGI's help in monitoring the progress of emission reductions, were also tested with the use of GHGI in climate action planning It was found that if the GHGI was found significantly helpful in identifying sources and quantifying emissions, it was more likely to be significantly used in climate action planning. However, if the GHGI was not found significantly helpful in identifying and quantifying emissions, it was more likely to be not used significantly in forming a CAP. Similarly, if the GHGI significantly helped in monitoring the progress of emission reductions, there were more chances of it being used significantly in forming CAP/SP; whereas, if the GHGI did not help significantly, there were more chances of it being not used significantly.

Two more variables were also tested for association - GHGI's facilitation in saving costs through identification of suitable mitigation measures and the use of GHGI in making decisions regarding emission reduction measures. It was observed that if the GHGI significantly helped in savings costs it was more likely to be very helpful in informing decision regarding emission reduction measures. Similarly, if the GHGI did not significantly help in savings costs it was more likely to be not very helpful in informing decisions either.

6.2. Recommendations

Based on the research outcomes, recommendations will be relevant to: IHE administration, sustainability coordinators, and faculty; leaders of voluntary programs; and policy makers; along with students who want to be actively involved in IHE climate change initiatives. A key take away from this study and suggestion to the institutions that intend to reduce their carbon footprint, is to start by conducting a GHGI, as indicated by others as well (American College and University Presidents Climate Commitment, n. d.; United States Environmental Protection Agency, n. d.; Zhaurova, 2008). The inventory helps institutions understand their emissions profile and identify options for emission reductions (Moerschbaecher & Day Jr. 2010; Zhaurova, 2008). The information generated by the GHGI is very useful and is recommended to be used in forming strategies to reduce the emissions (United States Environmental Protection Agency, n. d.). It is also advised to conduct inventories regularly so as to monitor progress towards the goal of carbon neutrality. This is important because sometimes institutions expect their emissions are reducing as a result of the reduction measures they have taken; however, in reality there net emissions are growing as a result of activities such as campus expansion, population growth, increased research, and so on. Thus GHGI can help them track their emissions record (Klein-Banai & Theis, 2011; Blackhurst et a., 2011; Letete et al., 2011; Jaye, 2011; Klein-Banai et al., 2010). GHGI typically incur minimal costs if any to conduct and offers several benefits, including identifying cost effective emission reduction options (Bader & Bleischwitz, 2009).

It is also recommended to ensure the facilities office on board while planning and conducting the GHGI. This offers two benefits; facilities department can provide significant help in gathering data for GHGI and it has the capacity to make use of the inventory information in controlling campus activities towards climate commitment.

6.3. Directions for future research

Due to time constraints, a targeted sample was surveyed in this research. It is recommended that any future research on this topic should take a sample that is larger and representative of all institutions of higher education in the country. Future research should include institutions that are not committed to any voluntary programs. This will explain and predict the applicability of findings to signatory and non-signatory institutions alike. An important aspect that was initially intended to be studied in this project was the constraints that institutions face in application of inventory information in planning and decision making. However, due to problems with the phrasing of the question about constraints in the survey questionnaire, it was excluded from analysis. Assessing the constraints can help generate information that can be used to make the inventory application easier; therefore, it is recommended that future research should consider studying the obstacles to climate change and GHGI initiatives.

In addition follow-up interviews with the respondents can be conducted to gather information that cannot be gathered through a survey, for instance to acquire more specific details about the institutional factors involved in conducting and using GHGI that vary widely across the institutions.

Furthermore, this research focused on those institutions only that had conducted the GHGI. It can be useful to study climate change mitigation at those institutions as well that had not conducted GHGI. A comparison between the two types of institutions can help determine which approach is more effective in reducing their carbon-footprint.

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Appendix A: Consent form, approved by the Institutional Review Board

DUQUESNE UNIVERSITY

600 FORBES AVENUE ♦ PITTSBURGH, PA 15282

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE:	Role of greenhouse gas inventories in climate change mitigation at the institutions of higher education.
INVESTIGATOR:	Sadaf Tehmina Student of MS Environmental Science & Management 327 North Neville Street, Apt. 1, Pittsburgh PA 15213 Cell number 646.354.8745
ADVISOR: (if applicable:)	Dr. John F. Stolz Director, Centre for Environmental Research and Education Bayer School of Natural and Environmental Sciences 412.396.6333
SOURCE OF SUPPORT:	This study is being performed as partial fulfillment of the requirements for the master's degree in Environmental Science & Management at Duquesne University
PURPOSE:	You are being asked to participate in a research project that seeks to investigate the role of greenhouse gas inventories in climate change mitigation at the institutions of higher education in the United States. To participate, you are being asked to take a survey that consists of some questions about the greenhouse gas inventory of your institution**.** The survey will take about 10 minutes of your time.

RISKS AND BENEFITS: There are no risks associated with participation in this research greater than those encountered in everyday life. The outcomes of the study will help in better understanding the use of inventories in mitigating climate change.

COMPENSATION: There is no compensation for participation in this study. However, if you would like to have a summary of the outcomes of this study please email Sadaf Tehmina at sadaftehmina87@gmail.com and we would be glad to share the summary of outcomes with you.

CONFIDENTIALITY: Your institution's name on the survey will only be used to keep track of the survey submission so that duplication can be avoided. Once the data is downloaded to statistical software for analysis, the name of the institution will be removed and a numerical code, as in 1, 2, and so on will be assigned to the response in order to maintain anonymity. The data will be stored on a password-protected personal computer of the Principal Investigator.

No identity will be made in the data analysis and in the outcome report. Your response(s) will only appear in statistical data summaries. All data will be deleted within one year of the completion of the study.

RIGHT TO WITHDRAW: You are under no obligation to participate in this study. You are free to withdraw your consent to participate, for any reason at any time before the submission of the survey, by not completing and submitting the survey. However, once you submit the survey it would be impossible to remove your data because the study is anonymous and it would be impossible to track your submission.

VOLUNTARY CONSENT: Proceed to the survey only if you agree to the following

I have read the above statements and understand what is being requested of me. I also understand that my participation is voluntary and that I am free to withdraw my consent for any reason at any time before the submission of the survey by not completing and submitting the survey. However, once I submit the survey it cannot be removed then, because it is an anonymous study and it will be impossible to track my survey submission in order to be able to delete it.

I understand that should I have any further questions about my participation in this study, I may call:

1. Ms. Sadaf Tehmina
   MS Environmental Science and Management
   Duquesne University
   Phone: 646 354 8745
2. Dr. John F. Stolz
   Director, Centre for Environmental Research and Education
   Bayer School of Natural and Environmental Sciences
   Duquesne University
   Phone: 412.396.6333
3. Dr. Linda Goodfellow
   Chair of the Duquesne University Institutional Review Board
   412-396-6326

This study has been approved by Duquesne University Institutional Review Board.

On these terms, I certify that I am willing to participate in this research project. I understand that by submitting the completed survey I voluntarily consent to participate in this project.

If you consent to participate in this survey please proceed to the next page to fill out the survey.

Appendix B: Questionnaire for survey

1. Name of the institution:

____

2. Who, at your institution, decided to create a GHG emissions inventory? You can select more than one option if it was a combined decision of a couple or more of the following people.
   - President or Chancellor
   - Administration or Facilities Management
   - Sustainability officer or a sustainability committee
   - A faculty member
   - A student for his/her research project
   - Other ________

3. Among the following options, select the reasons why your institution decided to create a greenhouse gas inventory.

	Yes, it was the primary reason.	It was the secondary reason.	Not sure about this.	No, it was not reason.
To generate baseline information of GHG emissions for formulating a plan/policy/strategy for reducing greenhouse gas emissions				
To identify the cost-effective mitigation options				
In requirement of applying for LEED certification for campus building(s)				
It was a faculty member's or/and a student's research project				
To fulfill a requirement of a commitment to a voluntary initiative				

or program, for instance ACUPCC, The 2030 Challenge, AASHE, and so on. If yes, please specify the program ______				

4. Who conducted the GHG emissions inventory of your institution? You can select more than one option if it was done by a group of some of the following people.
    - A person or a team from the facilities department
    - A person or a team from the university's sustainability office
    - A faculty member or faculty team
    - A student or a team of students, who may or may not be supervised by a faculty member
    - A consultant
    - Other ________

5. Did the project of creating a greenhouse gas inventory require financial support?
    - Yes, our institution had to pay a consultant for conducting the GHG emissions inventory
    - Yes, our institution had to pay a stipend to a student for conducting the GHG emissions inventory
    - Yes, our institution had to purchase a GHG emissions calculation tool or software
    - No, it didn't cost anything
    - Other _______

6. Has your institution taken any measures to reduce its greenhouse gas emissions in the recent years?

- Yes, our institution has taken a number of measures to reduce its emissions
- Yes, our institution has taken a few measures to reduce its emissions
- No, our institution has not taken any measures to reduce its emissions
- Don't know

7. How much, if any, emission reduction has your institution been able to achieve within the last decade?

- 0%
- 1% to 5%
- 6% to 10%
- More than 10%
- Don't know

8. Did your greenhouse gas inventory facilitate decision making regarding which emission reduction measures to take?

- Yes, it was very helpful in decision making
- Yes, it was slightly helpful in decision making
- No, it was not helpful in decision making
- No, our institution did not use it for decision making

9. Does your institution have either a climate action plan or policy?

- Yes
- No
- Don't know

10. If yes for question 9 above did your institution use its greenhouse gas inventory to form the climate action plan or policy?

- Yes, the inventory was used to a significant extent.
- Yes, the inventory was used to a small extent
- No, the inventory was not used at all.
- Don't know

11. Did your institution's GHG emissions inventory help you with the following?

	Yes, significantly	Yes, slightly	No, did not help
Identifying the sources and quantifying the greenhouse gas emissions of your institution.			
Saving costs by identifying the suitable energy use reduction options or other promising mitigation measures			
Monitoring the progress of greenhouse gas emission reductions			
Raising climate change awareness at your institution			
Using the greenhouse gas inventory as a pedagogical tool			

12. If your institution’s greenhouse gas inventory did not facilitate or lead to any mitigation action, what among the following were the reasons behind that?

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
Lack of commitment from the administration					
Lack of effective distribution of the inventory results to the administration or the decision-making authorities					
Lack of resources to implement mitigation practices					
Lack of a need to undertake mitigation because of absence of emission control regulations					
Unreliability of the inventory owing to the inaccuracies in the inventory information					
The limitation of the greenhouse gas inventories to take into account the future growth factors.					

Appendix C: Chi-square results

Table: *Presence of sustainability entity and participation in decision-making*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.369[a]	1	.012		
Continuity Correction[b]	4.679	1	.031		
Likelihood Ratio	7.125	1	.008		
Fisher's Exact Test				.026	.013
Linear-by-Linear Association	6.266	1	.012		
N of Valid Cases	62				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 4.50.
b. Computed only for a 2x2 table

Table: *Presence of sustainability entity and participation in conducting GHGI*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	10.528[a]	1	.001		
Continuity Correction[b]	8.319	1	.004		
Likelihood Ratio	14.012	1	.000		
Fisher's Exact Test				.002	.001
Linear-by-Linear Association	10.358	1	.001		
N of Valid Cases	62				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 4.50.
b. Computed only for a 2x2 table

Table: *Estimated reduction in emissions and presence of sustainability entity*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.023[a]	1	.880		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.023	1	.879		
Fisher's Exact Test				1.000	.585
Linear-by-Linear Association	.023	1	.881		
N of Valid Cases	62				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 4.21.

b. Computed only for a 2x2 table

Table: *Estimated reduction in emissions and institution type*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	7.968[a]	1	.005		
Continuity Correction[b]	6.486	1	.011		
Likelihood Ratio	8.173	1	.004		
Fisher's Exact Test				.006	.005
Linear-by-Linear Association	7.840	1	.005		
N of Valid Cases	62				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.89.
b. Computed only for a 2x2 table

Table: *Estimated reduction in emissions and institution level*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	10.176[a]	1	.001		
Continuity Correction[b]	8.405	1	.004		
Likelihood Ratio	11.264	1	.001		
Fisher's Exact Test				.001	.001
Linear-by-Linear Association	10.011	1	.002		
N of Valid Cases	62				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.48.
b. Computed only for a 2x2 table

Table: *Estimated reduction in emissions and community setting*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.021[a]	2	.600
Likelihood Ratio	1.024	2	.599
Linear-by-Linear Association	1.004	1	.316
N of Valid Cases	62		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.42.

Table: *Estimated reduction in emissions and GHGI's effectiveness in informing decisions*
Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.918[a]	1	.088		

Continuity Correction[b]	2.087	1	.149		
Likelihood Ratio	2.933	1	.087		
Fisher's Exact Test				.116	.074
Linear-by-Linear Association	2.871	1	.090		
N of Valid Cases	62				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 10.76.
b. Computed only for a 2x2 table

Table: *Inventory's effectiveness in informing decisions and Sustainability institute, office, committee, or position*
Crosstab

		Sustainability institute, office, committee, or position		Total
		No	Yes	
Inventory's effectiveness in informing decisions	Not very helpful	5	34	39
	Very helpful	4	19	23
Total		9	53	62

Table: *Inventory's effectiveness in informing decisions and Sustainability institute, office, committee, or position*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.244[a]	1	.622		
Continuity Correction[b]	.014	1	.904		
Likelihood Ratio	.239	1	.625		
Fisher's Exact Test				.715	.443
Linear-by-Linear Association	.240	1	.624		
N of Valid Cases	62				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 3.34.
b. Computed only for a 2x2 table

Table: *Inventory's effectiveness in informing decisions and Conducted by Facilities department*
Crosstab

		Conducted by facilities department		Total
		No	Yes	
Inventory's effectiveness in informing decisions	Not very helpful	25	14	39
	Very helpful	10	13	23
Total		35	27	62

Table: *Inventory's effectiveness in informing decisions and Conducted by facilities department*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.503[a]	1	.114		
Continuity Correction[b]	1.735	1	.188		
Likelihood Ratio	2.502	1	.114		
Fisher's Exact Test				.184	.094
Linear-by-Linear Association	2.463	1	.117		
N of Valid Cases	62				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 10.02.
b. Computed only for a 2x2 table

Table: *Inventory's effectiveness in informing decisions and Conducted by sustainability office*
Crosstab

		Conducted by sustainability office		Total
		no	yes	
Inventory's effectiveness in informing decisions	Not very helpful	19	20	39
	Very helpful	12	11	23
Total		31	31	62

Table: *Inventory's effectiveness in informing decisions and Conducted by sustainability office*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.069[a]	1	.793		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.069	1	.793		
Fisher's Exact Test				1.000	.500
Linear-by-Linear Association	.068	1	.794		
N of Valid Cases	62				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 11.50.
b. Computed only for a 2x2 table

Table: *Estimated reduction in emissions and GHGI's use in forming CAP/SP*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.218[a]	1	.040		
Continuity Correction[b]	3.237	1	.072		
Likelihood Ratio	4.271	1	.039		
Fisher's Exact Test				.047	.036
Linear-by-Linear Association	4.150	1	.042		
N of Valid Cases	62				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 14.03.
b. Computed only for a 2x2 table

Table: *Presence of sustainability entity and GHGI's use in forming CAP/SP*
Crosstab

		Sustainability institute, office, committee, or position		Total
		No	Yes	
GHGI's use in CAP	used significantly	4	28	32
	not used significantly	5	25	30
Total		9	53	62

Table: *Presence of sustainability entity and GHGI's use in forming CAP/SP*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.217[a]	1	.642		
Continuity Correction[b]	.011	1	.917		
Likelihood Ratio	.217	1	.642		
Fisher's Exact Test				.728	.457
Linear-by-Linear Association	.213	1	.644		
N of Valid Cases	62				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 4.35.
b. Computed only for a 2x2 table

Table: *Participation of facilities department in conducting GHGI and GHGI's use in forming CAP/SP*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.738[a]	1	.009		
Continuity Correction[b]	5.473	1	.019		

Likelihood Ratio	6.890	1	.009		
Fisher's Exact Test				.012	.009
Linear-by-Linear Association	6.630	1	.010		
N of Valid Cases	62				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 13.06.
b. Computed only for a 2x2 table

Table: *Participation of sustainability office in conducting GHGI and GHGI's use in forming CAP/SP*
Crosstab

		Conducted by sustainability office		Total
		no	yes	
Inventory's use in CAP	used significantly	15	17	32
	not used significantly	16	14	30
Total		31	31	62

Table: *Participation of sustainability office in conducting GHGI and GHGI's use in forming CAP/SP*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.258[a]	1	.611		
Continuity Correction[b]	.065	1	.799		
Likelihood Ratio	.259	1	.611		
Fisher's Exact Test				.800	.400
Linear-by-Linear Association	.254	1	.614		
N of Valid Cases	62				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 15.00.
b. Computed only for a 2x2 table

Table: Identifying sources & quantifying emissions *and GHGI's use in CAP/SP*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	14.319[a]	1	.000		
Continuity Correction[b]	12.112	1	.001		
Likelihood Ratio	16.282	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	14.088	1	.000		
N of Valid Cases	62				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.77.
b. Computed only for a 2x2 table

Table: *Monitoring progress of emission reductions and GHGI's use in CAP/SP*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	18.627[a]	1	.000		
Continuity Correction[b]	16.488	1	.000		
Likelihood Ratio	19.689	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	18.327	1	.000		
N of Valid Cases	62				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 13.55.
b. Computed only for a 2x2 table

Table: *GHGI's effectiveness in informing decisions and GHGI's facilitation in saving costs*
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.729[a]	1	.017		
Continuity Correction[b]	4.323	1	.038		
Likelihood Ratio	5.576	1	.018		
Fisher's Exact Test				.027	.020
Linear-by-Linear Association	5.636	1	.018		
N of Valid Cases	62				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.19.
b. Computed only for a 2x2 table

Appendix D: Measures of Association Results

Table: *Presence of sustainability entity and participation in decision-making Directional Measures*

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.175	.165	.969	.333
		Participation of sustainability entity in decision-making Dependent	.226	.207	.969	.333
		Presence of a sustainability entity Dependent	.000	.000	.[c]	.[c]
	Goodman and Kruskal tau	Participation of sustainability entity in decision-making Dependent	.103	.056		.012[d]
		Presence of a sustainability entity Dependent	.103	.062		.012[d]
	Uncertainty Coefficient	Symmetric	.104	.067	1.502	.008[e]
		Participation of sustainability entity in decision-making Dependent	.083	.055	1.502	.008[e]
		Presence of a sustainability entity Dependent	.139	.086	1.502	.008[e]

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Cannot be computed because the asymptotic standard error equals zero.
d. Based on chi-square approximation
e. Likelihood ratio chi-square probability.

Table: *Presence of sustainability entity and participation in decision-making*
Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.321			.012
	Cramer's V	.321			.012
	Contingency Coefficient	.305			.012
N of Valid Cases		62			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

Table: *Presence of sustainability entity and participation in conduction*
Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.225	.160	1.252	.211
		Who conducted - Sustainability office? Dependent	.290	.198	1.252	.211
		Sustainability institute, office,committee, or position Dependent	.000	.000	.[c]	.[c]
	Goodman and Kruskal tau	Who conducted - Sustainability office? Dependent	.170	.039		.001[d]
		Sustainability institute, office,committee, or position Dependent	.170	.056		.001[d]
	Uncertainty Coefficient	Symmetric	.204	.054	3.116	.000[e]
		Who conducted - Sustainability office? Dependent	.163	.052	3.116	.000[e]

		Sustainability institute, office,committee, or position Dependent	.273	.052	3.116	.000[e]

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Cannot be computed because the asymptotic standard error equals zero.
d. Based on chi-square approximation
e. Likelihood ratio chi-square probability.

Table: *Presence of sustainability entity and participation in conduction*
Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.412			.001
	Cramer's V	.412			.001
	Contingency Coefficient	.381			.001
N of Valid Cases		62			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

Table: *Estimated reduction in emissions and institution type*
Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.188	.075	2.140	.032
		Institution type Dependent	.000	.000	.[c]	.[c]
		Estimated percentage of emissions reduction Dependent	.310	.125	2.140	.032
	Goodman and Kruskal tau	Institution type Dependent	.129	.084		.005[d]
		Estimated percentage of emissions reduction Dependent	.129	.083		.005[d]
	Uncertainty	Symmetric	.101	.067	1.489	.004[e]

	Coefficient	Institution type Dependent	.107	.071	1.489	.004[e]
		Estimated percentage of emissions reduction Dependent	.095	.064	1.489	.004[e]

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Cannot be computed because the asymptotic standard error equals zero.
d. Based on chi-square approximation
e. Likelihood ratio chi-square probability.

Table: *Estimated reduction in emissions and institution type*
Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.359			.005
	Cramer's V	.359			.005
	Contingency Coefficient	.337			.005
N of Valid Cases		62			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

Table: *Estimated reduction in emissions and institution level*
Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.178	.137	1.193	.233
		Institution level Dependent	.000	.000	.[c]	.[c]
		Estimated percentage of emissions reduction Dependent	.276	.199	1.193	.233
	Goodman and Kruskal tau	Institution level Dependent	.164	.080		.002[d]
		Estimated percentage of emissions reduction Dependent	.164	.077		.002[d]

	Uncertainty Coefficient	Symmetric	.144	.075	1.873	.001[e]
		Institution level Dependent	.159	.082	1.873	.001[e]
		Estimated percentage of emissions reduction Dependent	.131	.070	1.873	.001[e]

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Cannot be computed because the asymptotic standard error equals zero.
d. Based on chi-square approximation
e. Likelihood ratio chi-square probability.

Table: *Estimated reduction in emissions and institution level*
Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.405			.001
	Cramer's V	.405			.001
	Contingency Coefficient	.375			.001
N of Valid Cases		62			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

Table: *Estimated reduction in emissions and GHGI's use in forming CAP/SP*
Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.220	.149	1.384	.166
		Inventory's use in CAP Dependent	.233	.168	1.233	.217
		Estimated percentage of emissions reduction Dependent	.207	.174	1.070	.284
	Goodman and Kruskal tau	Inventory's use in CAP Dependent	.068	.064		.042[c]

		Estimated percentage of emissions reduction Dependent	.068	.064		.042[c]
	Uncertainty Coefficient	Symmetric	.050	.047	1.052	.039[d]
		Inventory's use in CAP Dependent	.050	.047	1.052	.039[d]
		Estimated percentage of emissions reduction Dependent	.050	.047	1.052	.039[d]

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Based on chi-square approximation
d. Likelihood ratio chi-square probability.

Table: *Estimated reduction in emissions and GHGI's use in forming CAP/SP*
Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	-.261			.040
	Cramer's V	.261			.040
	Contingency Coefficient	.252			.040
N of Valid Cases		62			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

Table: *Participation of facilities department in conducting GHGI and GHGI's use in forming CAP/SP*
Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.263	.153	1.587	.113
		Inventory's use in CAP Dependent	.300	.165	1.550	.121
		Who conducted - Facilities dept? Dependent	.222	.185	1.070	.284

	Goodman and Kruskal tau	Inventory's use in CAP Dependent	.109	.078		.010[c]
		Who conducted - Facilities dept? Dependent	.109	.079		.010[c]
	Uncertainty Coefficient	Symmetric	.081	.060	1.354	.009[d]
		Inventory's use in CAP Dependent	.080	.059	1.354	.009[d]
		Who conducted - Facilities dept? Dependent	.081	.060	1.354	.009[d]

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Based on chi-square approximation
d. Likelihood ratio chi-square probability.

Table: *Participation of facilities department in conducting GHGI and GHGI's use in forming CAP/SP*
Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	-.330			.009
	Cramer's V	.330			.009
	Contingency Coefficient	.313			.009
N of Valid Cases		62			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

Table: *Identifying sources & quantifying emissions and GHGI's use in CAP/SP*
Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.273	.054	3.512	.000
		Uses - Identifying sources & quantifying emissions Dependent	.000	.000	.[c]	.[c]

		Inventory's use in CAP Dependent	.400	.097	3.512	.000
	Goodman and Kruskal tau	Uses - Identifying sources & quantifying emissions Dependent	.231	.086		.000[d]
		Inventory's use in CAP Dependent	.231	.079		.000[d]
	Uncertainty Coefficient	Symmetric	.214	.085	2.392	.000[e]
		Uses - Identifying sources & quantifying emissions Dependent	.246	.094	2.392	.000[e]
		Inventory's use in CAP Dependent	.190	.079	2.392	.000[e]

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Cannot be computed because the asymptotic standard error equals zero.
d. Based on chi-square approximation
e. Likelihood ratio chi-square probability.

Table: *Identifying sources & quantifying emissions and GHGI's use in CAP/SP Symmetric Measures*

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.481			.000
	Cramer's V	.481			.000
	Contingency Coefficient	.433			.000
N of Valid Cases		62			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

Table: *Monitoring progress of emission reductions and GHGI's use in CAP/SP Directional Measures*

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.

	Lambda	Symmetric	.517	.125	3.207	.001
		Uses - Monitoring progress of emission reductions Dependent	.500	.138	2.702	.007
		Inventory's use in CAP Dependent	.533	.120	3.275	.001
Nominal by Nominal	Goodman and Kruskal tau	Uses - Monitoring progress of emission reductions Dependent	.300	.116		.000[c]
		Inventory's use in CAP Dependent	.300	.116		.000[c]
	Uncertainty Coefficient	Symmetric	.230	.095	2.429	.000[d]
		Uses - Monitoring progress of emission reductions Dependent	.231	.095	2.429	.000[d]
		Inventory's use in CAP Dependent	.229	.094	2.429	.000[d]

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Based on chi-square approximation
d. Likelihood ratio chi-square probability.

Table: *Monitoring progress of emission reductions and GHGI's use in CAP/SP Symmetric Measures*

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.548			.000
	Cramer's V	.548			.000
	Contingency Coefficient	.481			.000
N of Valid Cases		62			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

Table: *GHGI's effectiveness in informing decisions and GHGI's facilitation in saving costs*
Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.108	.093	1.079	.281
		Uses - Savings costs Dependent	.000	.000	.[c]	.[c]
		Inventory's effectiveness in informing decisions Dependent	.174	.148	1.079	.281
	Goodman and Kruskal tau	Uses - Savings costs Dependent	.092	.077		.018[d]
		Inventory's effectiveness in informing decisions Dependent	.092	.076		.018[d]
	Uncertainty Coefficient	Symmetric	.075	.063	1.190	.018[e]
		Uses - Savings costs Dependent	.084	.069	1.190	.018[e]
		Inventory's effectiveness in informing decisions Dependent	.068	.057	1.190	.018[e]

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Cannot be computed because the asymptotic standard error equals zero.
d. Based on chi-square approximation
e. Likelihood ratio chi-square probability.

Table: *GHGI's effectiveness in informing decisions and GHGI's facilitation in saving costs*
Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	-.304			.017
	Cramer's V	.304			.017

	Contingency Coefficient	.291		.017
N of Valid Cases		62		

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.